UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

STRATEGIC ROADMAP TO IMPLEMENT AN AMR SURVEILLANCE AND MONITORING SYSTEM

United Nations Industrial Development Organization (UNIDO)
September 2023

WORLD BANK GROUP

Deliverable 2.1.6 on

Strategic Roadmap to implement an AMR Surveillance and monitoring system

Work Package 75, Sub-Activity 1.6

This report has been compiled as part of Work package 74, Sub-activity 1.6 to Develop a strategic roadmap for developing an integrated AMR surveillance and monitoring system.

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DISCLAIMER

Abbreviations and Acronyms

AMR	Antimicrobial Resistance
AMU	Antimicrobial Use
AST	Antimicrobial Susceptibility Testing
BLRI	Bangladesh Livestock Research Institute
BVC	Bangladesh Veterinary Council
CDIL	Central Disease Investigation Laboratory
CLSI	Clinical and Laboratory Standards Institute
DGDA	Directorate General of Drug Administration
DGHS	Directorate General of Health Services
DLS	Department of Livestock Services
DVH	District Veterinary Hospital
EQA	External Quality Assurance
ESBL	Extended-Spectrum Beta-Lactamase
EUCAST	European Committee on Antimicrobial Susceptibility Testing
FDIL	Field Disease Investigation Laboratory
ISO	International Organization for Standardization
LIMS	Laboratory Information Management System
LDDP	Livestock and Dairy Development Project
MoFL	Ministry of Fisheries and Livestock
MoHFW	Ministry of Health and Family Welfare
MOU	Memorandum of Understanding
NRL	National Reference Laboratory
ToR	Terms of Reference
WGS	Whole Genome Sequencing

CONTENTS

EXECUTIVE SUMMARY

The strategic roadmap to implement an antimicrobial resistance (AMR) surveillance and monitoring system is developed in the context of the United Nation Industrial Development Organization (UNIDO)-led Package 75 of the Livestock and Dairy Development Project (LDDP).

This roadmap aims at providing a prioritized list of concrete and coordinated actions for stakeholders in Bangladesh to implement an integrated foodborne AMR surveillance and monitoring system in livestock and foods of animal origin (foodborne AMR surveillance).

By enabling better understanding of the sources of infection and transmission of AMR in humans, animals and the environment, foodborne AMR surveillance gives a crucial contribution to achieve improved public health.

An efficient foodborne AMR surveillance system is based on generation and analysis of validated data on antimicrobial use (AMU) in livestock and AMR in livestock and foods of animal origin, which are used for advising policy, monitoring interventions, evaluating marketing authorisations of antimicrobials, supporting antimicrobial stewardship initiatives, and supporting risk assessment.

Government support and funding are fundamental to enable such a complex framework. A detailed economic assessment conducted within UNIDO-led Package 75 of the LDDP estimated that costs for sustainable investments (in the past and future) required to make the AMR surveillance system fully functional until 2041 are nearly 1,900 LAC BDT (around 1.700,000 USD). In addition, annual running costs, that increase over time (with increasing scope and laboratories joining the system) are estimated to be 107.6 LAC BDT (around 100,000 USD) now and 1,078.1 LAC BDT (around 985,000 USD) in the long term (2041).

Coordinated actions between DGDA, DGHS and DLS are needed to produce data on AMU in livestock and to use such information to promote responsible AMU.

A functional network led by the National Reference Laboratory (NRL) and composed by laboratories producing quality-assured results is needed to conduct AMR surveillance activities ranging from sample collection to data analysis and reporting. This report details key areas to develop such networks as well as the stakeholders most suited to address each area.

Finally, a digital system to regularly report, analyse and share AMU and AMR surveillance data should be developed along with the establishment of a surveillance network.

This roadmap builds on the many activities performed by UNIDO national and international experts within Package 75 of the LDDP. For each of these activities, reports of technical specifications, which describe how to implement the actions listed in the roadmap, have been issued, as referenced in the relevant sections.

Given the public health consequences of AMR in livestock and foods of animal origin, it is advisable that the actions listed in this roadmap are initiated as soon as possible in a collaborative spirit across stakeholders in Bangladesh.

BACKGROUND

The strategic roadmap to implement antimicrobial resistance (AMR) surveillance and monitoring system is developed in the context of the Livestock and Dairy Development Project (LDDP),
a World Bank-funded project with the overall objective to promote productivity growth, enhance market access, and improve risk management among smallholder farmers and agro-entrepreneurs in Bangladesh.

Specifically, this roadmap is the result of the United Nations Industrial Development Organization (UNIDO) contribution to sub-component C2 of the LDDP, which focuses on food safety and public health by addressing food safety and quality assurance. This roadmap contributes to the achievements of Output 2 (Sub-activity 1.6 Package 75) focusing on the conceptual development of an AMR surveillance system, monitoring of antimicrobial use (AMU) and risk mitigation in animals and foods of animal origin.

Surveillance and monitoring of AMR in bacteria from livestock and foods of animal origin, that can be transmitted to humans via food, is defined "**foodborne AMR surveillance**" by international organisations like the World Health Organisation (WHO) and the Codex Alimentarius, among others (WHO, 2015; Codex Alimentarius, 2021).

Implementation of a "foodborne AMR surveillance" system, is **critical to safeguard public health** (WHO, 2017). By including multiple elements of the food chain, and also AMU data, it is possible to enable better understanding of the sources of infection and transmission of AMR in humans, animals and the environment (WHO, 2017).

This roadmap builds on the numerous activities and reports compiled by UNIDO national and international AMR experts within Package 75 of the LDDP, following international guidance described in the Global Action Plan on AMR (WHO, 2015).

The Global Action Plan on AMR outlines five objectives that are key to ensure lasting availability of effective medicines for treatment of microbial diseases:

- Objective 1: Improve awareness and understanding of antimicrobial resistance through effective communication, education and training;
- Objective 2: Strengthen the knowledge and evidence base through surveillance and research;
- Objective 3: Reduce the incidence of infection through effective sanitation, hygiene and infection prevention measures;
- Objective 4: Optimize the use of antimicrobial medicines in human and animal health;
- Objective 5: Develop the economic case for sustainable investment that takes account of the needs of all countries, and increase investment in new medicines, diagnostic tools, vaccines and other interventions.

The activities undertaken by UNIDO national and international AMR experts within WP 75 of the

LDDP fit perfectly within these objectives as summarised in Table 1. A clear understanding of these activities and the use of the generated reports, which have been submitted to LDDP, are fundamental to apply the actions set out in this roadmap, as detailed in relevant sections in this document.

Table 1. UNIDO activities conducted in Package 75 of the LDDP project, that fulfil the objectives of the Global Action Plan on AMR

Objective of the Global Action Plan on AMR	UNIDO activities within Package 75
Improve awareness and understanding of antimicrobial resistance through effective communication, education and training	- Awareness-raising session on draft Codex Guidelines on integrated AMR surveillance and monitoring - Awareness-raising on AMR risk analysis principles and provision of recommendations to the Government for AMR risk analysis framework - Building relationships among relevant public health and veterinary services to ensure structured data sharing among each other
Strengthen the knowledge and evidence base through surveillance and research	- A review of existing policies, strategies, laws and capacity building initiatives leading current efforts in antimicrobial resistance related to the livestock sector, including veterinary drug registration - Writing of a policy paper for an integrated AMR surveillance and monitoring framework, focusing on possible synergies - Creation of a technical guide for bacterial antimicrobial susceptibility testing - A framework to support the development of a data management system, following regional efforts in AMR surveillance and monitoring and identify data analytics efforts to facilitate risk management and risk assessment - Stakeholder consultation and development of a technical guide on sampling strategies for public authorities to ensure data integrity and better practices in AMR surveillance and monitoring - Assessment of existing national database and systems for data collection on surveillance and monitoring of microbial, chemical hazards and drug residues in animal and animal origin food and development of a technical guide on standardized data collection methods based on a national sampling strategy for microbial and chemical hazards as well as residues of antimicrobials along an animal origin food value chain
Reduce the incidence of infection through effective sanitation, hygiene and infection prevention measures	- Conducted a study with recommendations on risk mitigation measures related to AMR (incl. risk communication and technical recommendations for GAHP scheme under package 74) based on existing international best practices
Optimize the use of antimicrobial medicines in human and animal health	- Not applicable as beyond the scope of Work package 75 of the LDDP

Objective of the Global Action Plan on AMR	UNIDO activities within Package 75
Develop the economic case for sustainable investment that takes account of the needs of all countries, and increase investment in new medicines, diagnostic tools, vaccines and other interventions	- An economic assessment for national AMR surveillance system based on possible setups for a national framework on AMR surveillance was undertaken.

OBJECTIVE

The objective of this roadmap is **to provide stakeholders in Bangladesh with a prioritised list of concrete and coordinated actions to establish an integrated foodborne AMR surveillance and monitoring system**, with actions spread over the short (2025), medium (2030) and long (2041) term.

An effective AMR surveillance system is based on the generation and analysis of validated data on AMR that can be used to advise policy, monitor interventions, evaluate antimicrobial marketing authorisations, support antimicrobial stewardship initiatives and support risk assessment.

This is in line with objective 3 in the Global Action Plan on AMR: "Strengthen the knowledge and evidence base through surveillance and research".

STEPS IN SETTING UP A FOODBORNE AMR SURVEILLANCE SYSTEM

According to the Codex Alimentarius "Guidelines on integrated monitoring and surveillance of foodborne antimicrobial resistance" (CXG 94-2021), monitoring and surveillance programme(s) should be designed to generate data on AMR and AMU in livestock and food sectors to inform risk analysis.

AMU and AMR surveillance follow two parallel tracks that are detailed below. Once generated and validated, the AMR surveillance data should be linked with AMU data in the different livestock species to generate information, that can be used for advising policy and monitoring the effect of any interventions.

AMU surveillance

In Bangladesh, surveillance of AMU in human and veterinary sectors falls within the mandate of DGDA, whereas use of antimicrobials in livestock is within the competency of the Department of Livestock Services (DLS). Enhanced coordination between DGDA and DLS is needed for activities related to approval and use of veterinary antimicrobials. As DGHS has also been involved in regulating AMU in livestock, for example by imposing the ban on use of colistin, further

coordination between DGHS and DLS should be established.

A Memorandum of Understanding (MoU) should be signed between DLS and DGDA, and DLS and DGHS. Such MoU should constitute the evidence that DGDA, DGHS and DLS are aligned regarding AMU in livestock and collaborate to link AMU and AMR data and to produce a periodic surveillance report.

A system for veterinary AMU data collection, sharing and storage should be established. This system should be electronic and possibly collect granular data on type of use, animal group and route of administration. It could be considered to allow all Bangladesh Veterinary Council (BVC)-registered veterinarians to report to such system, and to include in the code of conduct of BVC the obligation to report AMU information.

An SOP including the elements necessary for AMU data collection should be jointly prepared by DLS and DGDA. Elements to consider include:

- Type of data availability (sales vs. use)
- Harmonization of the nomenclature of antimicrobial agents with international standards
- Identification of the livestock species for which the antimicrobials were intended to be used
- Identification of the desired level of detail (e.g. production type, route of administration or reason for use)
- Information on antimicrobial dose, dosing interval and duration
- Technical units of measurement for reporting antimicrobial sales or use

Finally, it should be emphasised that Bangladesh already has legislation that regulates sale of antimicrobials for animals as prescription-only drugs and prohibits the use of antibiotics for growth promotion. However, compliance with the legislation is limited. **Mechanisms to ensure compliance with legislation on AMU should be established.**

AMR surveillance

Essential requirements for implementing a laboratory-based surveillance system for foodborne AMR can be grouped in four categories:

1. Government support
2. Laboratory capacity and quality management
3. Materials and supplies
4. Sample and data management, including collection, analysis, reporting and storage

1. Government support

Establishment and sustainability of an AMR surveillance system depends on internal government funding and support from policy-makers. The Government of Bangladesh has already implemented activities to support foodborne AMR surveillance including the development of a national action plan (NAP) for AMR, the establishment of Central Disease Investigation Laboratory (CDIL; under the DLS) as the national reference laboratory (NRL) for AMR surveillance and the forming of an AMR intersectoral committee. Two main elements still need to be addressed, which are the provision of legislative support and government funding for implementation of surveillance activities. Additionally, once the legislative support has been issued, mechanisms to ensure compliance with legislation should be also established.

1. 1 Legislation on monitoring and reporting foodborne AMR

Legislation for AMR surveillance should describe the laboratory network in charge of AMR surveillance activities, the livestock populations and food categories to be sampled, the sampling design to be followed, the bacterial species to be tested, and the analytical methods to be used. The legislation should be flexible enough to allow for voluntary use of methods such as whole genome sequencing (WGS) that are currently available to a limited number of laboratories, but have clear advantages compared to traditional antimicrobial susceptibility testing (AST) methods. Importantly, technical conditions on the WGS technique to ensure comparability of data should also be defined in the legislation.

1. 2 Funding

Sustainable government funding is key to implementation of a national foodborne AMR surveillance system. Investment by donor agencies can be fundamental to create laboratory capacity but then dependence from external financing should stop. While utilising funds from donor agencies, a central coordination should tightly monitor that duplication of work is avoided. **Stable government funding should be available for hiring and training personnel and ensuring laboratory operations.**

A detailed economic assessment conducted within UNIDO-led Package 75 of the LDDP estimated that costs for sustainable **investments** (in the past and future) required to make the AMR surveillance system fully functional until 2041 are nearly **1,900 LAC BDT (around 1.700,000 USD)** (Habimana, 2023).

In **addition**, annual **running costs, that increase over time** (with increasing scope and laboratories joining the system) are estimated at

- 107.6 LAC BDT (around 100,000 USD) now,
- 284.0 LAC BDT (around 260,000 USD) in the short term (2025),
- 593.4 LAC BDT (around 490,000 USD) in the medium term (2030) and

- 1,078.1 LAC BDT (around 985,000 USD) in the long term (2041) (Habimana, 2023).

To optimise use of resources and facilitate implementation, **it is recommended that the AMR surveillance utilises biological samples and/or bacterial strains already collected in the framework of other national control programs focusing on food safety**. In this context, it would be beneficial to find synergies with the inspection programme developed as part of UNIDO activities in Package 74 of the LDDP.

2. Laboratory capacity and quality management

A national foodborne AMR surveillance programme relies on the existence of a network of veterinary public health laboratories with the appropriate staffing, equipment and infrastructure capacity to collect and process samples according to standardised and harmonised methods, and to produce and share data that are quality assured according to international standards (ISO). Specific actions needed in Bangladesh to build and sustain this network are presented below.

2. 1 Laboratory network

A network of laboratories led by CDIL and including two Field Disease Investigation Laboratories (FDILs) under DLS, namely FDIL Feni and FDIL Joypurhat, is currently in place in the country. Furthermore, the AMR laboratory at the Bangladesh Livestock Research Institute (BLRI) has been designated NRL for AMR research. Whereas this network is extremely valuable to pilot implementation of foodborne AMR surveillance, it is necessary to include additional laboratories to reach capacity for nation-wide surveillance activities.

Expansion of the network can happen via recruitment both of existing FDILs and of veterinary microbiology laboratories in academic institutions. Currently, there is a plan to expand the network to include four sentinel laboratories, including FDIL Barisal, Sylhet, Sirajganj and Jashore, by 2025, and additional four sentinel laboratories, including FDIL Manikganj, Gaibandha, Chattogram and Gopalganj, by 2030.

For additional FDILs to participate in AMR surveillance activities, investments for infrastructure, equipment and personnel are needed.

Although not currently foreseen, it may be necessary to consider including in the foodborne AMR surveillance network some veterinary microbiology laboratories of academic institutions. In some of these laboratories, capacity for AMR surveillance activities including sample collection and processing, antimicrobial susceptibility testing and data analysis, is already established at least to some extent, which would limit the costs for capacity building, although accreditation of methods is often lacking. As further detailed in paragraph 2.3, it is critical that AMR surveillance activities are performed according to methods accredited by a regulatory authority, which preferably provides accreditation according to international standards (ISO).

Based on the composition of the network, it may be necessary to reach an agreement on ownership of isolates and data, though it must be mandatory for laboratories in the network to provide isolates and data to the NRL upon request. Additionally, the network should operate

according to SOPs issued by the NRL and commit to contribute to activities such as annual meetings, data collection workshops, symposia and lectures.

All these aspects should be included in **Terms of Reference (ToR) specifically designed for the network.**

The nominated **NRL** (i.e. the CDIL) **should be officially assigned specific roles and responsibilities** for leading and supporting the network of laboratories on the one hand, and for providing advisory services to the Authorities on the other hand. In particular, the NRL **should be mandated to develop proficiency in the following core functions** (ECDC, 2010):

1. Reference methods

- Have up-to-date reference methods in operation for specific /disease characterisation
- Offer diagnostic confirmation services

2. Reference material resources

- Develop, maintain and/or have access to relevant reference materials
- Provide and/or facilitate access to reference material for laboratories in the network

3. Scientific advice

- Provide scientific advice and recommendations to public health authorities
- Provide technical support for policy development
- Provide advice and support to laboratories (i.e. including activities such as conducting workshops and other training activities based on needs but also for the implementation of new methods and policies)

4. Collaboration

- Participation in regional/international AMR networks
- Participation in other regionally or internationally relevant projects and initiatives, including research and development activities
- Participation in, and contribution to, international surveillance (WOAH and FAO programmes)

5. Monitoring, alert and response

- Provide data to national surveillance institutes or, if part of a national surveillance institute, to other appropriate bodies

- Provide early warnings, advice and technical support in case of occurrence of unexpected resistance phenotypes.

Finally, the long-term vision of national AMR stakeholders is to include all 64 District Veterinary Hospital (DVH) in passive AMR surveillance activities by 2041. Adequate ToR will need to be written to ensure that the contribution of DVHs is fully aligned with the foodborne AMR surveillance activities.

The technical and economic considerations for implementing the expansion of the network of laboratories involved in foodborne AMR surveillance are detailed in Habimana (2023) and Siddiky and Giasuddin (2023).

2. 2 SOPs

The laboratories in the foodborne AMR surveillance network should operate according to standardized and harmonized procedures for sample collection and processing, bacterial isolation and identification, AST and data management. Currently, laboratories that reported to conduct some foodborne AMR surveillance activities in the country confirmed that they operate according to SOPs that, however, were not always based on existing international standards, were not harmonised between laboratories and were not regularly updated. The NRL should be in charge of **producing and regularly updating SOPs on sample collection and transport, sample processing, isolation and identification of bacteria, antimicrobial susceptibility testing, storage of isolates, referral to the NRL, data management and quality management**. These SOPs should be aligned with international standards (ISO methods) for all situations in which such ISO standards exist. In case of unavailability of ISO standards, the NRL should develop SOPs based on internationally validated methods. Regarding antimicrobial susceptibility testing, the available ISO standard (ISO 20776-1:2019) focuses solely on broth microdilution and is therefore relevant mainly for the NRL, as it is expected that most laboratories in the AMR surveillance network will implement AST using disk diffusion. Both the Clinical and Laboratory Standards Institute (CLSI) and the European Committee on Antimicrobial Susceptibility Testing (EUCAST) provide guidance and interpretive criteria for disk diffusion. It is strongly recommended to perform foodborne AMR surveillance according to EUCAST guidance using epidemiological cut-off values (ECOFFs) for interpretation of results (WHO, 2017). The reasons for this are: i) ECOFFs are by definition the most appropriate values for interpretation of AST results in a foodborne AMR surveillance context since they only depend on microbiological characteristics and allow sensitive detection and quantification of acquired and expressed resistance mechanisms, which is the main aim of a foodborne AMR surveillance (Kahlmeter and Turnidge, 2022); and ii) EUCAST guidance is freely available online, whereas CLSI standards must be purchased annually, which is an unnecessary cost in situations in which financing is limited. In the Authors' experience in various countries, it is not infrequent to observe laboratories using expired CLSI guidance which,

if not explicitly stated, may be problematic when comparing surveillance results across years.

The technical details for developing SOPs for sample collection and transport, sample processing, bacterial isolation and identification, antimicrobial susceptibility testing, and storage of isolates are presented in Chowdhury et al. (2023) and Siddiky and Giasuddin (2023). Of note, the bacterial species/antimicrobial combinations recommended for AST by Chowdhury et al. (2023) reflect the current epidemiological situation. As the epidemiology of AMR changes over time, it is expected that the bacterial species/antimicrobial combinations under surveillance will also change over time. The technical details for developing SOP for data management are presented by Hanks (2023).

2. 3 Quality Management System (QMS) and accreditation

Laboratories within a national foodborne AMR surveillance network should operate according to accredited methods. While accreditation may be done also according to national standards, it is by far preferable to operate according to internationals standards for bacteriology laboratory (ISO). The costs of certification, time involved and audits constitute a burden for laboratories, and sufficient funding should be allocated to these activities.

All laboratories in the foodborne AMR surveillance network should establish internal quality assurance programmes and should periodically participate in external quality assurance (EQA) trials. The NRL should be officially recognised as a mentor to establish internal quality assurance programmes in the laboratories in the network and as a provider of EQA, ideally according to ISO/IEC 17043:2023. The NRL itself should periodically participate in EQA conducted by reliable providers (i.e. accredited according to ISO standards or equivalent). Additionally, it should be formalised in a SOP how the EQA results are used for feedback and education.

The NRL should have the capacity to perform confirmatory testing of exceptional phenotypes and validate unexpected results using both phenotypic and genotypic methods. It should be **established as mandatory for laboratories in the network to send to the NRL isolates with phenotypes that are unexpected or of particular public health relevance**. As the epidemiology of AMR changes over time, **the NRL should periodically issue a list of bacterial species and phenotypes of relevance for referral to the NRL**.

2. 4 Training

Training in methods described in SOPs should be organised periodically either by the NRL or by outsourcing to academic institutions of proven capacity to deliver training courses on these topics. A cascade system, by which trainees transfer the acquired knowledge internally in their laboratory, should also be established and documented.

Detailed information and practical examples for the development of training courses in sample collection and processing and antimicrobial susceptibility testing is presented in Chowdhury et al. (2023).

Training personnel in correct use and maintenance of equipment and storage of consumables

and isolates is also critical and should be performed periodically. The NRL should be in charge of training the trainers, who will then cascade the acquired knowledge locally in their laboratories.

3. Materials and supplies

A functional AMR surveillance programme requires facilities with access to stable water and electricity supplies, reliable equipment, and sustainable supply of quality consumables.

At present, only few laboratories have appropriate facilities and equipment to take active part in foodborne AMR surveillance activities and therefore it will be necessary to **increase the number of laboratories having the capacity to be recruited in the foodborne AMR surveillance network** by renovation of facilities and purchase of equipment (see paragraph 2.1).

Regarding consumables, in dialogues with stakeholders it appeared that consumables used currently for AMR surveillance activities are purchased mainly by relying on donors' funding. The dependency of external financing for consumables is not sustainable and should end and a government budget explicitly dedicated to foodborne AMR surveillance activities (see paragraph 2.1). To optimize use of resources, **the NRL should receive an official mandate to aid the laboratories in the networks with tender procedures and should provide a list of reliable manufacturers based on quality verification.** It is well known that there are huge variations in quality of consumables from different manufacturers, and therefore in tender procedures costs and verified quality should both be considered. The NRL should also be in contact with manufacturers to address supply-chain issues, if any.

Creation and maintenance of a repository of isolates (biobank) is also an important aspect related to materials for AMR surveillance. The biobank should include both strains used for quality assurance purposes, to be further distributed to the laboratories in the network when needed, and strains from the surveillance programme that have phenotypes of public health relevance (see also paragraph 2.3).

4. Sample collection, data management, analysis and reporting

Currently, some samples are collected and some AMR data are generated from livestock and food in the country, however there is no standardized approach and national coordination regarding sample collection, data management, analysis and reporting.

Guidance for sampling (where, what, when and how to sample) should be developed to ensure that the data generated are representative of the livestock population and the food of animal-origin available in the country. The sampling framework should be adopted in a stepwise manner to account for the laboratory capacity and human and financial resources available, that will increase over time. In several countries having a nationwide foodborne AMR surveillance, activities started through small projects, focusing for example on **specific resistance phenotypes** of public health relevance. Based on current epidemiology of resistance, phenotypes for piloting a surveillance programme could be extended-spectrum beta-lactamases (ESBLs) and carbapenemases in indicator Escherichia coli from livestock and food, and linezolid- and vancomycin-resistant Enterococcus faecium and E. faecalis. Alternatively, it could be considered to perform **sampling on a rotating basis** as done in the European Union, in which sampling for

foodborne AMR surveillance is mandatory in ruminants and derived products in odd years and in poultry and derived products in even years.

Access to a laboratory information management system (LIMS) allowing for storage of epidemiological information, test results, data validation and computerized transmission of results should be guaranteed for the laboratories participating in foodborne AMR surveillance activities, since electronic systems reduce workload and errors, and allow standardisation of data. Importantly, such LIMS should be common to all laboratories to allow interoperability.

The technical details for developing a sampling framework are presented by Siddiky and Giasuddin (2023), while information on the requirements and possible solutions for data management using electronic systems is thoroughly elaborated by Hanks (2023).

CONCLUDING REMARKS

The key actions recommended in this document, and summarised in the Appendix, represent the steps necessary to establish and implement a foodborne AMR surveillance programme in Bangladesh.

During workshops conducted within the scope of UNIDO-led Package 75 of the LDDP, it became clear that there is awareness of the extent to which foodborne AMR threatens public health, and a gap analysis showed that, what is mostly needed to optimise use of available resources for foodborne AMR surveillance, is clear leadership, enhanced coordination and compliance with existing legislation (Bortolaia et al., 2023).

The **Government has a critical role in enabling foodborne AMR surveillance by providing the legislative framework and funding** for laboratories to be operational and empowered. Great attention should be given to **ensure sustainable funding for human resources, training, standardisation and accreditation of methods** at the CDIL (i.e. the NRL for AMR surveillance) first, and at additional laboratories in the foodborne AMR surveillance network afterwards. An economic assessment performed within Package 75 of the LDDP conducted by UNIDO International Economist estimated the funding required to make the AMR surveillance system fully functional until 2041 is nearly 1,900 LAC BDT (around 1.700,000 USD) for sustainable investments. In addition, annual running costs, that increase over time with increasing scope and laboratories joining the system, are estimated to be 107.6 LAC BDT (around 100,000 USD) now and 1,078.1 LAC BDT (around 985,000 USD) in the long term (2041) (Habimana, 2023).

It is clear that the NRL and the laboratory network have a fundamental role in AMR surveillance, and **explicit definition of roles and responsibilities, quality assurance and simplification of tender procedures for purchase of materials are necessary to develop a functional laboratory network.**

A framework to enable use of data is as important as a framework to generate data, and therefore **AMU and AMR data should be used to inform decision making and to provide the evidence for interventions for public health, food production and food safety purposes at**

least annually. Indicators to show the results of any interventions should be established – one example of **indicator could be the extent of reduction in the prevalence of AMR based on data collected over time**.

The described **actions can be implemented in a stepwise manner** involving initially a limited number of laboratories with the greatest capacity. Based on the experience from the early stages of implementation, actions can then be further tailored and the surveillance activities can be expanded to additional laboratories which, in the meantime, underwent capacity building processes.

This roadmap focuses exclusively on actions enabling foodborne AMR surveillance but it should be emphasised that several additional actions, that will directly affect AMU and therefore AMR, can be implemented within Objective 4 of the Global Action Plan on AMR: "Optimize the use of antimicrobial medicines in human and animal health". These include, for example, enhanced biosecurity and use of vaccines. Finally, once foodborne AMR surveillance is established, AMR surveillance in veterinary pathogens will likely represent the next step to completely fulfil the One Health strategy on AMR surveillance.

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APPENDIX

Table A1. Summary of the key actions described in this Roadmap that are necessary for the establishment and implementation of a foodborne AMR surveillance programme in Bangladesh

Domain	Area	Responsible	Action	Outcome	Implementation period*
AMU	Government support	MoHFzW, MoFL	Provide a framework to ensure compliance with existing legislation	Existing legislation that mandates use of antimicrobials as prescription-only drugs and bans use of growth promoters is uniformly applied in livestock productions across the country	Short-term
		DGDA, DGHA, DLS	Sign a Memorandum of Understanding (MoU) between DGDA, DGHS and DLS	DGDA, DGHS and DLS are aligned regarding AMU in livestock and collaborate to link AMU and AMR data and produce a periodic surveillance report	Short-term
	Data management	DGDA, DLS	Establish an electronic system for veterinary AMU data collection, sharing and storage	Veterinary practitioners report AMU data (ideally, type of use, animal group and route of administration) to an electronic system to share and store data	Medium-term
		DGDA, DLS	Write a SOP describing AMU information to collect	AMU information is collected using standardised and harmonised information	Short-term
AMR	Government support	MoFL	Issue legislation and regulations for foodborne AMR surveillance	Livestock populations and food categories to be sampled, sampling design, bacterial species to be tested, and the analytical methods to be used are regulated at national level, which is critical for standardisation and harmonisation	Short-term

	MoFL	Mandate resistration of farms, animals, slaughter facilities and/or markets	Samples are collected according to rigorous sampling plans and are traceable	Short-term
	MoFL	Allocate funding specifically to AMR surveillance activities	Funding for accreditation, hiring and training personnel and ensuring laboratory operations is secured through government and is independent of donors' funding	Short-term
Laboratory capacity	MoFL, DLS	Expand laboratory network to ensure national coverage	Capacity and capability to process samples representing the livestock populations of the entire country	Long-term
	DLS	Create ToR for laboratory network	The laboratories in the network perform methods according to standard and harmonised methods, and participate in network activities	Short-term
	MoFL, DLS	Define roles and responsibilities of NRL	The NRL is proficient in core functions	Short-term
	DLS and AMR laboratory network	Write SOPs	The NRL, in collaboration with the laboratory network when appropriate, delelops SOPs for sample collection and transport, sample processing, isolation and identification of bacterial species selected for the surveillance, antimicrobial susceptibility testing, storage of isolates, referral to the NRL, data management and quality management	Medium-term

	DLS and AMR laboratory network	Assure quality of results	The laboratories in the network have an internal quality management system, participate in external quality assurance (EQA) trials and perform methods that are accredited by a regulatory authority	Short-term
	DLS and AMR laboratory network	Train in methods according to SOPs	The NRL conducts training periodically, and the laboratories in the network cascade the aquired knowledge internally	Short-term
Materials and supplies	MoFL	Simplify tender procedures	The NRL aids the laboratories in the networks with tender procedures and thereby available resources are optimised by avoiding duplications of efforts	Short-term
	DLS	Provide a list of reliable manufacturers based on quality verification	The laboratories use reagents of quality verified by the NRL	Short-term
	DLS	Establish a biobank	The NRL has a collection of isolates that can be used for reference purposes	Long-term
	DLS and AMR laboratory network	Regularly train in use and maintenance of equipment	The equipment is used correctly, which will prolong its life-span and will allow to obtain good quality results	Short-term
	DLS and AMR laboratory network	Regularly train in use and storage of reagents	Personnel safety is safeguarded and results of consistently good quality will be produced	Short-term
Sample collection, data management, analysis and reporting	DLS and AMR laboratory network	Develop a guidance for sampling	There is clarity and coordination among stakeholders regarding where, what, when and how to sample, and samples are representative of the livestock population and the food of animal-origin in the country	Short-term

		MoFL, DLS	Enable laboratories in the network to access a LIMS (ensuring interoperability in case different laboratories use different LIMS)	Epidemiological information and test results are stored electronically and results are transferred electronically from network laboratories to NRL with reduced workload and errors, and in a standardised way	Medium-term
AMU+AMR	Data management	DGDA, DLS	Link AMU and AMR data in different livestock species	Information for advising policy, monitoring interventions, evaluating marketing authorisations of antimicrobials, supporting antimicrobial stewardship initiatives, and supporting risk assessment is obtained	Medium-term
		DGDA, DLS	Create SOPs for data management, analysis and reporting	Data are collected and stored to maintain confidentiality and are analysed and reported regularly across stakeholders and possibly to the public in a transparent way	Short-term

* short term (2025), medium term (2030) and long term (2041), as detailed in Habimana (2023) and Siddiky and Giasuddin (2023).

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